Spatial and Temporal Patterns in Habitat Use and Depth Distribution of Witch Flounder: Implications for Stock Assessment

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Introduction

Until recently, witch flounder (a.k.a. 'grey sole'; *Glyptocephalus cynoglossus*) has received comparatively less research and management attention than other species in the New England groundfish complex. However, the 2015 update assessment indicated relatively low stock size and diagnostic issues, specifically an increased retrospective inconsistency, prompting a downward adjustment to the terminal year biomass (NEFSC 2015), which in turn prompted an initial recommendation to substantially reduce the acceptable biological catch for the stock (SSC 2015). This scientific recommendation was later revisited and revised in response to guidance from fishery managers that near-term risk tolerance could be greater, as well as the potential for the forthcoming benchmark stock assessment to resolve important scientific uncertainties (SSC 2016).

The effects of environmental change on the distribution and productivity of fishery resources on the Northeast Shelf is receiving increasing attention as the rate and magnitude of change accelerates, and fishery managers, scientists and fishermen struggle to keep pace (Walsh et al. 2015; Hare et al. 2016; Klein et al. 2016). Witch flounder provide an informative case study of the potential scientific responses to these issues given their unique patterns of habitat use and depth distribution, and especially the likely changes underway in these attributes due to environmental change. These patterns and changes might be linked to uncertainties in the stock assessment, or might call for new analytical approaches.

In order to support the 62nd Stock Assessment Workshop (SAW62) in addressing these issues, Environmental Defense Fund convened a work group to bring together and synthesize different data and perspectives on the witch flounder stock and fishery. Participants included representatives from federal government, state government, academia, an environmental NGO and three Northeast fishing communities, with expertise spanning ecology, oceanography, fisheries science, and commercial fishing operations. This working paper summarizes the findings and recommendations of that work group.

Habitat preferences

Witch flounder exhibit a high degree of habitat-specificity, preferring depressions in soft sediment areas and patches of soft sediment amidst more complex rocky structures (Fig. 1A). Witch flounder also prefer especially deep and cold habitats, being most commonly found in water temperatures less than 10°C and at depths greater than 50m (Cargnelli et al. 1999; Collette and Klein-MacPhee 2002). The optimal combination of substrate, temperature and depth conditions is often found in the bottom of basins and gullies beneath undersea peaks, ledges and banks.

These habitat preferences inhibited exploitation of the stock for many years due to the difficulty of bottom fishing in deep and structurally complex habitats. While some fishermen have long been able to target witch flounder in lower relief soft sediment habitats, such as areas within Massachusetts Bay (Fig. 1B), fishermen working in the more complex habitats utilized by the species only began to target witch flounder in earnest after the advent of technologies that provided more detailed understanding of bottom topography. Sonar systems that could visualize the seafloor and locate schools of fish became available to commercial fishing vessels in the 1980s, and later became more widely utilized in the early 1990s when bulky CRTs were replaced by more compact LCD displays. With these technologies, fishermen could "view" benthic features in real time. For vessels without these technologies, multi-beam bathymetric surveys provided fishermen with more detailed charts, and differential GPS enabled better recording of the location of good fishing grounds, as well as areas to be avoided. These technological innovations allowed fishing with the precision needed to navigate deeper and more complex habitats (Fig. 1B).

The greater importance of technology for harvest of witch flounder meant that development of the fishery lagged other groundfish species to some degree (Collette and Klein-MacPhee 2002). For example, catch of Gulf of Maine cod increased by approximately 30% from the mid-1970s to the mid-1980s (~10,000mt to ~13,000mt; NEFSC 2012), whereas catch of witch flounder increased by approximately 300% during the same period (~2,000mt to ~6,000mt; NEFSC 2012) as technology allowed more efficient fishing.

Catches of witch flounder are especially concentrated in those areas where suitable habitat is found (Fig. 2A). Aided by technological developments, fishermen with years of experience have developed the local ecological knowledge that is necessary to target witch flounder effectively in these complex, high-relief habitats. However, sampling in these complex habitats may be more problematic for larger survey vessels. Spatial patterns in trawl survey 'hangs' on hard, high-relief habitat features show concentrations in the same areas where witch flounder catches are highest (Fig. 2B). Even in areas where the structural complexity allows for survey sampling, small patches of soft sediments amidst rocky habitat might create micro-refuges where witch flounder would not be available to the survey gear (Fig. 1A).

These issues mean that survey indices are likely to be more uncertain for witch flounder relative to species that prefer habitats that are easier to sample. In fact, catches of witch flounder are relatively low on the stratified random trawl surveys that are used to inform the stock assessment for this species. Furthermore, swept-area biomass estimates will be biased downward if optimal habitats cannot be sampled representatively. Trends in relative biomass, on the other hand, would be more uncertain but not be biased, as long as the relative distribution of fish and the localized population dynamics are consistent through time among habitats and survey strata. However, there is evidence that the stock is becoming increasingly concentrated in deeper areas where complex habitats that are more difficult to sample are more prevalent, which suggests that the assumption of stationarity might not be valid.

Changes in depth distribution

Unlike many species along the Northeast Shelf, witch flounder are not yet exhibiting pronounced changes in latitudinal distribution (Fig. 3C). However, the species is exhibiting a distributional shift into deeper waters (Fig. 3E). This trend includes declining abundance in several shallower strata that are currently used in the assessment (01370, 01380, 01400) but increasing concentration in several deeper offshore strata (01220, 01290, 01300, 01360), including at least one survey stratum (01340) that is not currently used for the stock assessment (Fig. 3A).

Furthermore, fishermen report that the flatfish community as a whole was historically segregated by depth, with yellowtail flounder and winter flounder generally co-occurring at shallower depths, and witch flounder and American plaice ('dabs') co-occurring in deeper waters. However, in recent years, fishermen are observing increasing overlap among all of these species as warming waters drive the shallower species deeper. Therefore, inter-specific competition might be exacerbating temperature-driven changes in depth distribution of witch flounder.

In addition to the overall trend of a shift to deeper waters, there is evidence that the depth distribution of larger witch flounder is exhibiting even larger changes than the population as a whole (Fig. 4). This means that any habitat- or depth-related survey biases might be greatest with respect to the largest fish that contribute most to biomass estimates.

Finally, fishermen report that their ability to fish in many of the deep and complex habitats preferred by witch flounder has become increasingly limited through time due to increased deployment of fixed gear, especially lobster traps. The presence of fixed gear would also affect the ability of fishery-independent surveys to operate in these areas. Link and Demarest (2003) concluded that most trawl survey hangs through 2002 were due to permanent, natural features. However, fishing effort for and landings of American lobster in the Gulf of Maine stock area have increased dramatically since 2002, so the relative importance of natural features and fixed gears in inhibiting both mobile gear fishing and surveys has likely changed.

Summary and recommendations

The information reviewed above identifies four important issues that can affect the interactions between the witch flounder stock and surveys (as well as fisheries):

- Preference for deep, complex habitat that is more difficult to survey. Unless the there is a trend in distribution or dynamics of the stock among habitats, this would likely introduce greater uncertainty in relative abundance indices for the stock, but not necessarily bias.
- Shifting distribution to deeper habitats could introduce biases because the stock is becoming disproportionately distributed in areas that are more difficult to survey.
- Segregation among depths by size could exacerbate biases in abundance indices by disproportionately reducing catchability/availability of the largest fish that contribute most to biomass estimates and indices. If larger fish have become less available to the survey, it could also confound efforts to track cohorts over time and estimate mortality.
- Increasing deployment of fixed gear, especially lobster traps, in the areas preferred by witch flounder that are already more difficult to sample and the directional change in fishing effort could introduce bias, even in the absence of directional changes in depth distribution of fish.

Any of these issues could be problematic. In combination, these issues might introduce especially important uncertainties and biases into the assessment outcomes. It is unlikely that the effect of any or all of these factors would be to fundamentally change the current perception that the stock is at low biomass and not increasingly dramatically. However, addressing these issues could result in reduction of assessment uncertainties (e.g., retrospective patterns) that necessitate substantial downward adjustments to biomass estimates, or fine-tuning of the biomass estimates and resulting catch limits in ways that could benefit the socio-economic performance of the fishery. Accordingly, we offer the following seven recommendations, four that can potentially be adopted in the near-term within SAW62 and three that will likely require longer term attention on the research track:

<u>Near-term (SAW62)</u>

1. Include data from deeper survey strata in which witch flounder are becoming more prevalent, especially stratum 01340 in the central Gulf of Maine (Fig. 5).
2. Allow catchability to be estimated as a time varying parameter that is informed by one or more covariates (e.g., sea surface temperature, mean depth of survey catch) in response to the potential biases introduced by changes in depth distribution of the stock.
3. Consider a domed rather than flat-topped survey selectivity function to account for spatial population structure and fishing patterns, and the likelihood that larger fish are less available to the survey due to size-specific depth separation, with larger fish preferring the deeper and more complex areas that are more difficult to survey.
4. Include additional data sets as tuning indices in order to counter-balance the potential biases in the survey. These might include standardized CPUE of targeted fishing effort (e.g., Terceiro 2016) and the northern shrimp trawl survey, a long-running state-federal partnership that samples the deeper waters preferred by witch flounder (Fig. 6).

<u>Longer term (research track)</u>

5. Updated information on the distribution of fixed gears and the location of survey hangs should be analyzed with data on the distribution of witch flounder catch from surveys and the fishery in order to better characterize co-occurrence and potential biases.
6. The results from previous and ongoing net efficiency experiments should be included to inform catchability/selectivity estimates across a range of stocks. A workshop to review the outcomes of these studies and determine how best to incorporate those would be an efficient way of making those results more widely and consistently applicable to multiple assessments.
7. Industry-based surveys should supplement federal and state fishery-independent surveys in order to increase sample density and to more effectively sample deep, high-relief areas that are not sampled as effectively by larger vessels.

These recommendations most directly address SAW62 term of reference (TOR) #2:

> *Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.*

Although we do not address changes in growth, natural mortality or recruitment directly, it is possible that the distributional changes observed represent basin dynamics (MacCall 1990), whereby fish redistribute themselves in ways that optimize population growth and its constituent components. Therefore, these findings are also relevant to TOR #3:

> *Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.*

Finally, the longer term recommendations contribute to TOR #9:

Review, evaluate and report on the status of research recommendations from the last peer reviewed benchmark stock assessment. Identify new research recommendations.

References

Cargnelli LM, Griesbach SJ, Packer DB, Berrien PL, Morse WW, Johnson DL. 1999. Winter flounder, *Glyptocephalus cynoglossus*, life history and habitat characteristics. Essential Fish Habitat Source Document. NMFS-NE-139.

Collette BB, Klein-MacPhee G. 2002. *Bigelow and Schroeder's Fishes of the Gulf of Maine, Third Edition*. Smithsonian Books, Washington, DC.

Hare JA *et al*. 2016. A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. continental shelf. *PLoS ONE* 11: e0146756. doi:10.1371/journal.pone.0146756

Klein WS, Smith SL, Kritzer JP. 2016. Effects of climate change on four New England groundfish species. *Rev Fish Biol Fisheries* doi:10.1007/s11160-016-9444-z

Link JS, Demarest C. 2003. Trawl hangs, baby fish, and closed areas: a win–win scenario. *ICES J Mar Sci* 60: 930–938.

MacCall AD. 1990. *Dynamic Geography of Marine Fish Populations*. Washington Sea Grant Program, Seattle.

Northeast Fisheries Science Center (NEFSC). 2012. Assessment or Data Updates of 13 Northeast Groundfish Stocks through 2010. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 12-06.

Northeast Fisheries Science Center (NEFSC). 2015. Operational Assessment of 20 Northeast Groundfish Stocks, Updated Through 2014. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-24.

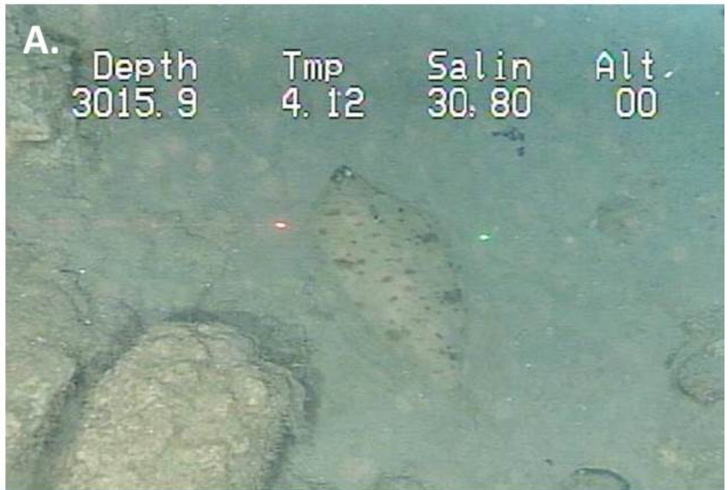
Scientific and Statistical Committee (SSC). 2015. Overfishing levels (OFLs) and acceptable biological catch (ABC) recommendations for groundfish stocks for fishing years 2016-2018. Report to the New England Fishery Management Council.

Scientific and Statistical Committee (SSC). 2016. Overfishing levels (OFLs) and acceptable biological catch (ABC) recommendations for witch flounder. Report to the New England Fishery Management Council.

Terceiro M. 2016. TOR 1: Description of commercial fishery Dealer Report trawl gear landings and effort and modeling landings rate (LPUE) data for witch flounder: 'Directed' Trips (=>40% of trip landings). SAW62 Witch flounder Working Paper: 8/16/16.

Walsh HJ, Richardson DE, Marancik KE, Hare JA (2015) Long-term changes in the distributions of larval and adult fish in the Northeast U.S. Shelf ecosystem. *PLoS ONE* 10: e0137382. doi:10.1371/journal.pone.0137382

Williams A, Kloser R, Barker B, Bax N, Butler A. 2003. A seascape perspective for managing deep-sea habitats. In: Shotton R (Ed.) *Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries, Part 1: Conference Reports*. Food & Agricultural Organization of the United Nations, Rome.



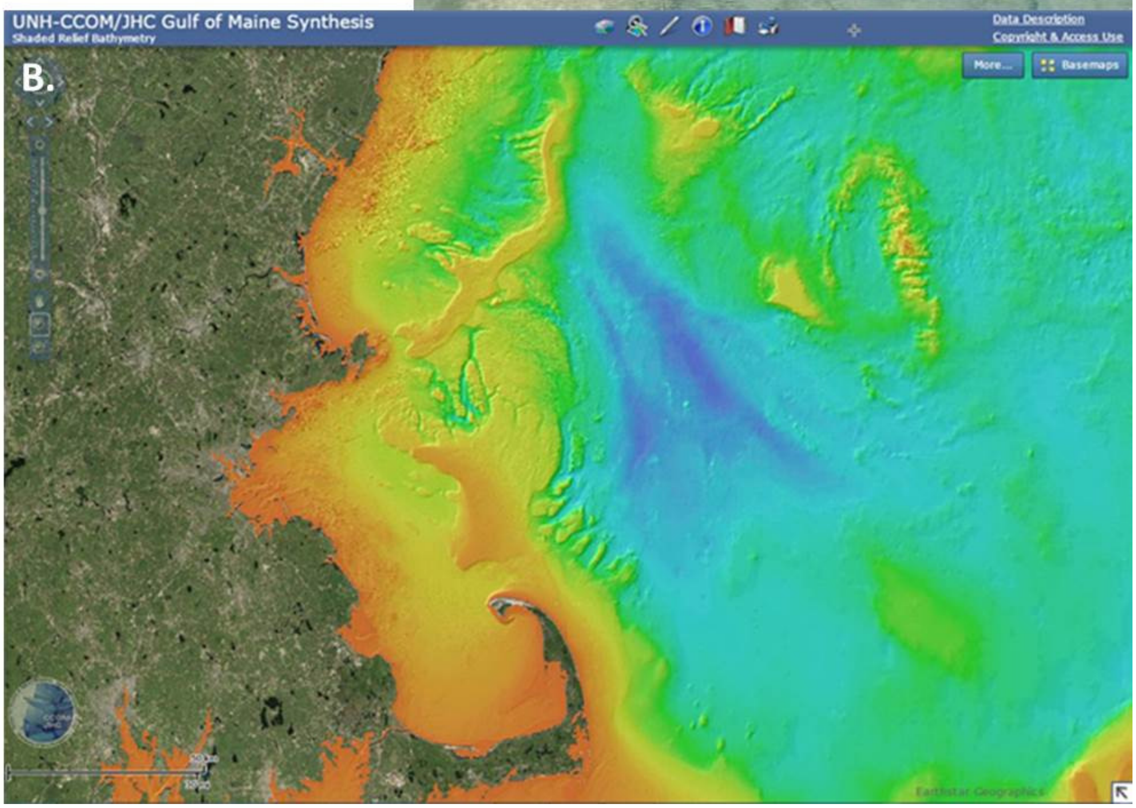


Figure 1. (A) A witch flounder on muddy substrate amidst rocky habitat in Oceanographer Canyon. (B) Bathymetry of the Western Gulf of Maine illustrating the structural complexity in areas preferred by witch flounder, especially off Cape Ann and the seaward side of Cape Cod. (A from Williams et al. 2003; B from UNH Center for Ocean and Coastal Mapping, http://ccom.unh.edu/project/jeffreys-ledge, accessed Sept. 6, 2016)

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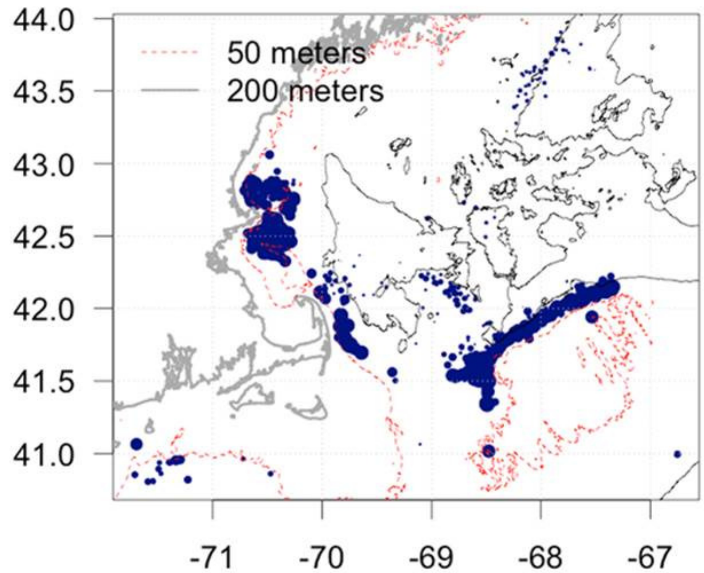

Figure 2. (A) Study fleet catches of witch flounder between July 15 and September 15 from 2007 to 2016. (B) Locations of trawl survey hangs of level 3 or greater from 1963 to 2002. Concentrations of areas that are more difficult to survey coincide with concentrations of witch flounder catch along the Northern Edge of Georges Bank, surrounding Cape Ann, and especially off the seaward shore of Cape Cod. (A from the NEFSC Northeast Cooperative Research Program Study Fleet; B from Link and Demarest 2003)

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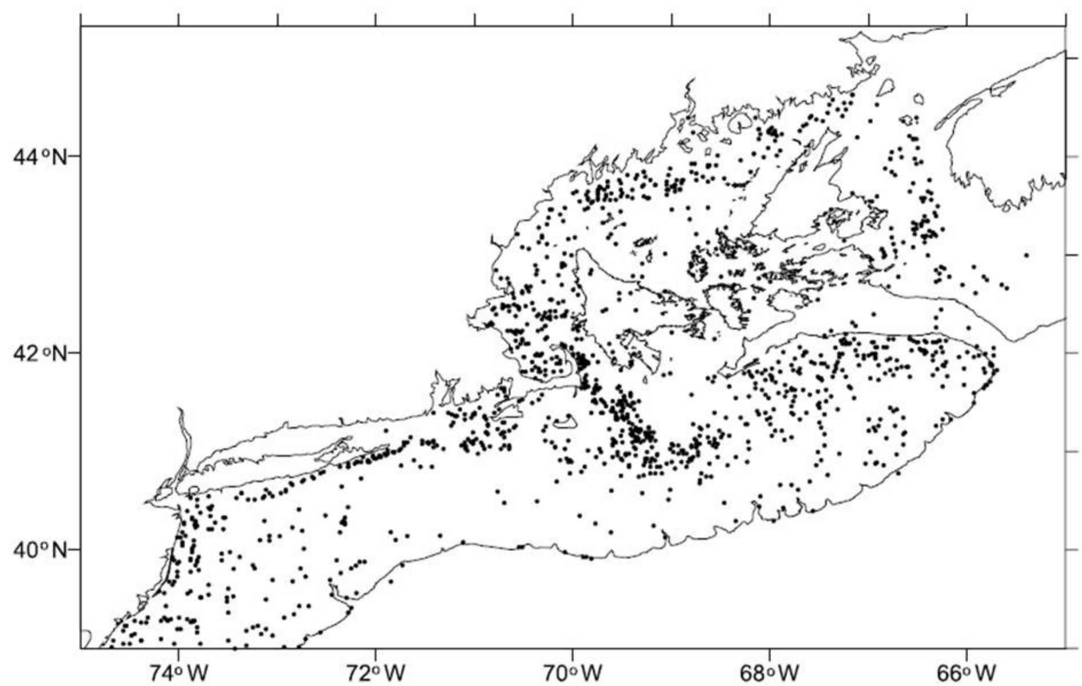

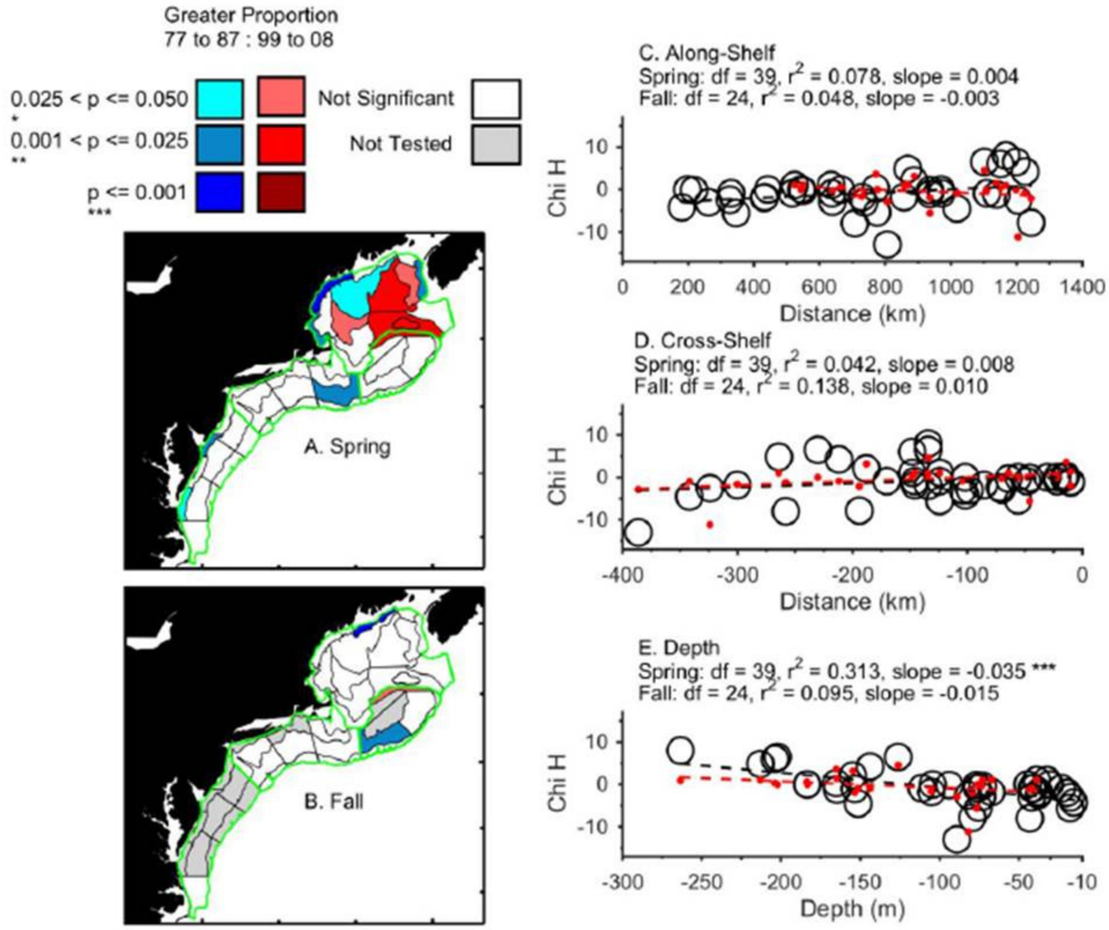

Figure 3. Spatial distribution of adult *Glyptocephalus cynoglossus* (Witch Flounder) on the Northeast U.S. Shelf Ecosystem. Change in distribution of adult *Glyptocephalus cynoglossus* in the spring (A; ○) and fall (B; •) were examined in the along-shelf (C), cross-shelf (D), and depth (E) directions. *Glyptocephalus cynoglossus* shifted significantly deeper (E) in the spring. (from Walsh et al. 2015)

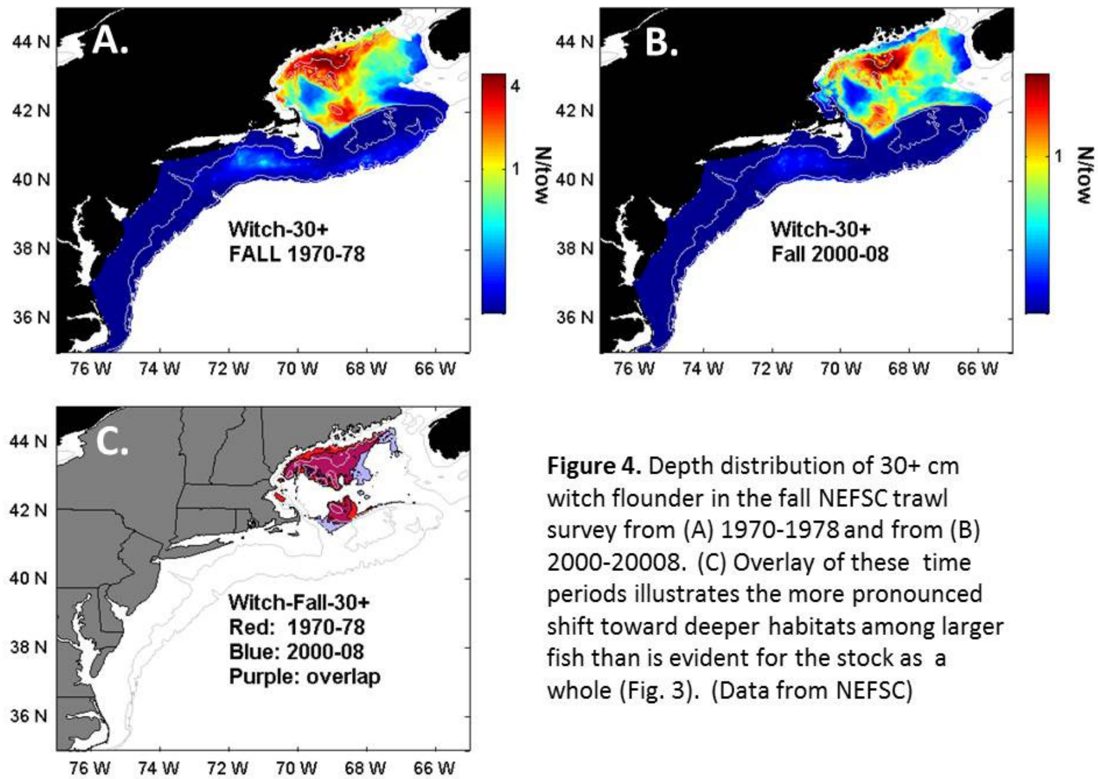

Figure 4. Depth distribution of 30+ cm witch flounder in the fall NEFSC trawl survey from (A) 1970-1978 and from (B) 2000-20008. (C) Overlay of these time periods illustrates the more pronounced shift toward deeper habitats among larger fish than is evident for the stock as a whole (Fig. 3). (Data from NEFSC)

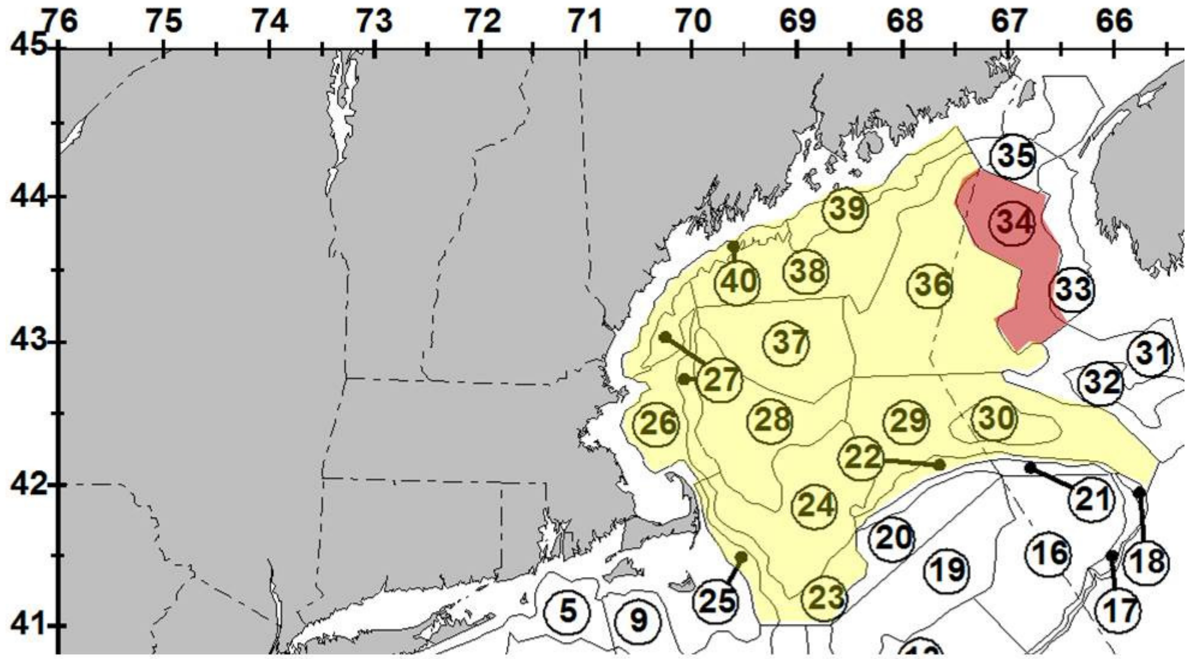

Figure 5. NEFSC bottom trawl survey offshore strata. Strata used for the witch flounder assessment (22-30, 36-40) are highlighted yellow, and the proposed additional stratum (34) is highlighted red.

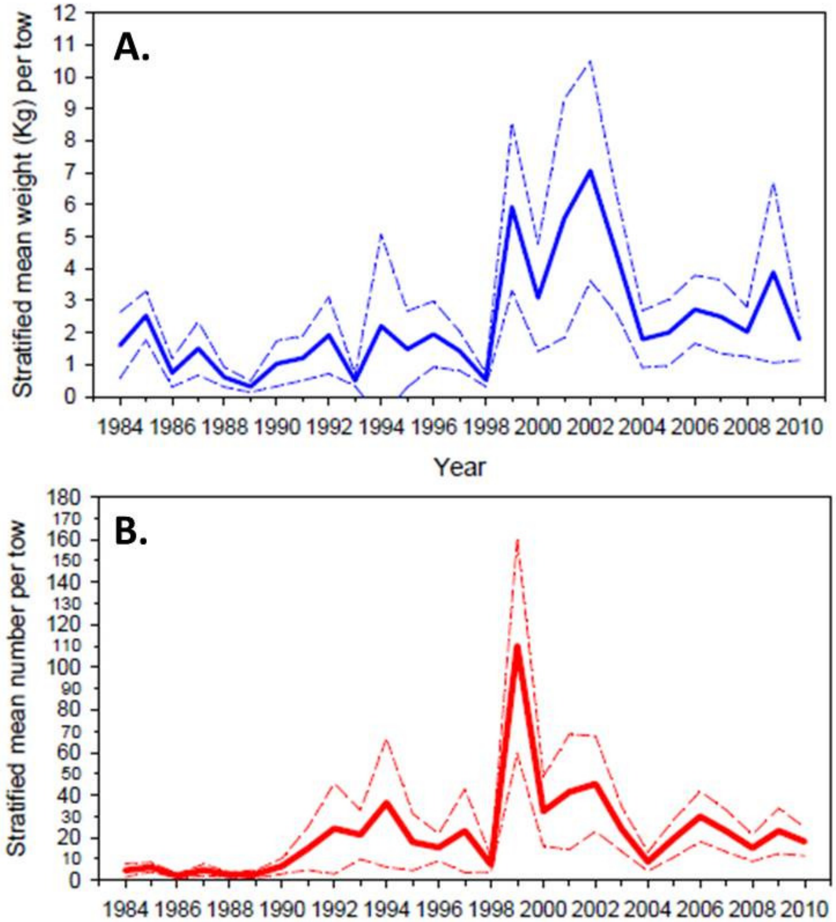

Figure 6. Catch of witch flounder in terms of (A) weight and (B) numbers from the cooperative state/federal northern shrimp survey. (see http://www.asmfc.org/fisheries-science/surveys#shrimp; figures from NEFSC 2012)